THE NEW MOVEMENT AMONG PHYSICS TEACHERS

CIRCULAR IV

In accordance with the programme for the conduct of this movement, there is submitted in this circular as a basis of discussion a portion of the proposed syllabus. It was thought unnecessary to submit the entire document until it is clear that the form and arrangement is the one desired by the physics teachers.

It is important that everyone should recognize the fact that this syllabus is submitted as a basis for discussion. It has not been acted on by the commission, and it is hoped that no member of the commission will approve it unless he is sure it is an advance in the right direction. It is very desirable that there be a free and wide-spread discussion of it, and that everybody who has any suggestions to make should make them freely and without reserve. If you see any point in which this syllabus can be improved, it is your duty to inform the commission of the fact. You are also urged, if you have an entirely new plan to suggest, to send in the scheme for consideration. All such suggestions will be brought before the commission for consideration.

The purpose of the commission in this work is twofold. First, to find out just what is wanted by the teachers as a whole for the improvement of physics teaching; and second, having found this out, to attempt to secure it for them. In order to attain these objects, it is very important that everyone should express his opinion freely, and it is hoped that this will be the case. If the members of the commission will give prompt attention to this work for a short time, the commission will be able to realize its purposes quickly, and much good to the teaching of our subject will result.

The course outlined in the following syllabus is supposed to be a one-year course in the third or fourth year of the secondary school. The course should be preceded in the first or second year by a simpler and more qualitative course in general physical science. The encouragement of the establishment of such courses is one of the aims of this outline.

Attention is particularly directed to the following points of this syllabus:

1. The subject-matter of the proposed course does not differ at all from that now given in the present physics courses. Hence any of the regular texts may be used, the lessons from the text being assigned by topics.

2. This syllabus differs from those now in use in two essential points: namely, in emphasis, and in organization.

As to the first, the emphasis has been laid on energy transformations and transferences, because these are the real subject of study in physics. This emphasis also adds unity to the course by centering the discussion on one thing.

The organization of the course follows readily if we agree to emphasize the energy phenomena. The arrangement sketched below shows how much simpler the outline becomes when arranged from this point of view. The subject-matter falls naturally under a few general principles, and many of the laws of the books are seen to be either special cases, or else essential to obtaining knowledge of the energy relations under discussion. Thus the laws of the lever, the law of moments, the laws of the pulleys, etc., all fall under the general work-principle, often called the law of machines. In heat, the ideas of temperature and of heat-quantity, the laws of boiling, of saturated vapors, Boyle's law, and that of Charles are all subsidiary to finding the relations between heat and work. This organization also gives a continuity to the course and justifies the introduction of many ideas which usually are introduced without justification.

3. An organization like this enables the teacher to use the scientific method, and to develop a habit of using it among the students. For example, he starts with a problem: How much work can a heat engine do under certain conditions? In the solution of this problem, he has to proceed inductively and to establish and use most of the important principles in heat. If the students are interested in the problem there will be no trouble in retaining their interest in the steps to its solution.

4. The topics enumerated in the subheads to the general principles in the syllabus are far too numerous to be treated satisfactorily in one year. This compels the teacher to select and use only those best suited to the particular conditions under which he works. It also lays stress on the necessity of the student's comprehending and being able to use the general principles which form the chief headings. This arrangement also gives the necessary flexibility to the syllabus.

5. The historical matter is introduced in such a way as to encourage laying weight on the connections between physics and other activities. When possible, the historical matter is placed first.

6. Topics are introduced from the general experiences of the student. The attempt is made to find first a problem from his own world in which he is interested, and then to proceed in the main inductively to its solution.

DEFINITION OF THE PHYSICS UNIT

1. The one-year course in physics should occupy at least two hundred and forty periods of forty-five min. each, e. g., six periods a week for forty weeks.

2. The work shall consist of two closely related parts, class work, and laboratory work. At least one-third of the time shall be devoted to the laboratory.

3. It is very essential that at least two of the six periods a week be arranged as a double period for laboratory work.

4. The class work shall include the study of at least one standard text.

5. In the laboratory, each student should perform at least forty individual experiments, both qualitative and quantitative as the teacher may require; but twenty quantitative experiments, each of which illustrates an important principle of physics, and no two of which illustrate the same principle, must be written up in ink in the notebook. The twenty experiments so written up should be selected to illustrate the starred topics in the syllabus. (The meaning of this may not be clear. The aims are: to allow the introduction of qualitative experiments if the teacher wishes; to allow but to discourage the experiments in learning to use measuring instruments merely as such; to allow but to discourage attempts at determining numerical coefficients and constants; and to take the emphasis off the apparatus and put it on the observation of phenomena. How may these aims be attained?)

6. In the class work, the student must be drilled to an understanding of the use of the general principles which form the chief headings. He must be able to apply these principles to the solution of simple, practical, concrete problems. The teacher may omit as many of the topics in the subheads as he thinks best, provided the student is able to use the general principle intelligently, and to give reasons for his belief in the validity of the principle.

7. Examinations should be framed to test the students understanding of and ability to use these general principles as indicated in paragraph 6.

8. The teacher is not required to follow the order of topics as indicated in the syllabus unless he wishes to do so.

SYLLABUS

NOTE.—It is hoped that additions rather than reductions will be made to the following outline, especially additions of experiments for both demonstration and laboratory. If only we can make the syllabus a source of suggestion to the teacher, instead of an incubus, much good will result.

INTRODUCTION

A. Weight. Center of gravity

a) Concept of weight illustrated by common experiences; some things heavy, others light.

b) Measurement of weight by spring balance in gram-weight and in pound-weight.

c) Graphical representation of weights by vectors pointing vertically downward. Scale of the plat.

d) Weight conceived as applied at a point, center of gravity. Experiments in balancing. Conditions for balance or equilibrium, namely, that the plumb line through the center of gravity falls within the base of support. Experimental determination of center of gravity. The meter-stick experiment, etc.

B. Force. Parallelogram of forces

a) Hang body on a string tied to a spring balance. Show that the balance reading is the same when the string hangs vertically downward and when it is passed over a pully so that the balance is not vertical. Concept of pulls similar to weight in other directions than vertical. Graphical representation by vectors in direction of force.

b) Two spring balances pulling against each other; readings are the same. Tension equal in both directions. Graphical representation by equal oppositely directed vectors.

c) Two spring balances pull against one in opposite direction; sum of the two equals the one. Vectors to represent this: vector sum.

**d*) Three spring balances pulling againts one another in any direction. Graphical representation by vectors. Addition of vectors to form a closed triangle. Composition of forces.

e) Summary and statement of the parallelogram of forces.

MECHANICS

1. Forces in liquids. Pascal's law

a) From familiar experience show that the total force on the bottom of a rectangular vessel equals the weight of the liquid.

b) When the area of the base is constant, the total force varies with the depth. When the depth is constant, it varies with the area. Pressure defined as force per cm^2.

c) One c.c. of water weighs a gram.

d) Pressure at a point the same in all directions.

e) Pressure of a confined liquid same on every sq. cm. of the containing vessel. Hydraulic press.

f) Summary. Pascal's law.

2. Pressure in gases. Atmospheric pressure and Boyle's law

a) From general experiences show evidences of atmospheric pressure.

b) Historical: Galileo, Torricelli, Pascal. Pumps: Siphon.

c) Barometer: Uses in meteorology.

d) Spring of air: Boyle's law.

e) Graphical representation of $PV = Const.$

3. Equilibrated pressures in fluids. Archimedes' principle

a) Show flotation of bodies less dense than water. Vectors representing weight of body and upward pressure of water.

**b*) Summary. Archimedes' principle.

c) Buoyancy: Bodies denser than water in water. Balloons.

**d*) Equal volumes of different substances have different weights. Specific gravity. Vectors showing weight of the body and the upward pressure of fluid.

4. Action of weight. Falling bodies

a) Bodies free to fall acquire velocity downward. Concept of uniform or average velocity, from running, boating, riding.

b) Measurement of velocity. Distance measured in ft. or cm.; time in sec. Velocity measured by distance divided by time. Symbols for velocity, $\frac{ft}{sec}$ $\frac{cm}{sec}$. Define velocity as rate of change for distance.

c) Algebraic representation of uniform or average velocity $v = s/t$. Graphical representation on a distance-time plot.

d) Note that in falling bodies a greater height of fall gives a greater velocity. Concept of variable velocity from cars, trains, autos starting and stopping, etc.

Concept of change in velocity in a time unit. Acceleration defined as rate of change of velocity.

e) Algebraic representation of uniform acceleration $a = V/t$ when body starts from or ends up at rest. Graphical representation of accelerated motion on distance-time plot. Measurement of acceleration in cm. and sec². Symbol for acceleration $\frac{\text{cm}}{\text{sec}^2}$.

f) Space passed over with uniformly accelerated motion starting from rest. $s = V/2t$.

g) Numerical value of acceleration of gravity.

h) Discussion as to whether g is the same for all bodies. Historical: Aristotle, Galileo, Newton.

5. **Work done in lifting against weight. Principle of external weight (law of machines)**

a) Idea of gravity work—lifting brick, hauling water, etc. Amount of work depends on two factors—weight lifted, and distance in a vertical direction. Agree to measure work by the product of wt.×ht. Units: ft.-lbs. or gm.-cm. Graphical representation of work on the wt.-ht. diagram.

b) Positive and negative work. Pendulum: Work done on it (positive) equals work it can do (negative).

c) Galileo's pendulum. Work done by pendulum not greater than work done on it. Work depends on difference of level, not on path from one level to the other. Mechanical energy may be measured by work.

d) Historical on the use of machines in doing work in antiquity and at the present time. Simple machines.

*e) Inclined plane. Work in lifting body up measured by weight × vertical ht. Practically work necessary to raise the body along the plane equals force × length. These works not equal in practice. *Fl.* is greater than *Wh.* Efficiency of the plane defined as *Wh./Fl.* As friction is reduced, *Fl.* becomes more nearly equal to *Wh.* In ideal case, $Fl = Wh$.

*f) Pulleys. Smaller weight acts through a greater height. *Wh.* not equal to wH. Efficiency. Work done by the pulleys cannot be greater than the work done on them. In the ideal case these works are equal.

*g) Levers. Equal arm has an efficiency = 1. Principle of moments from the work principle. When the weight of the lever has to be lifted, efficiency is less than 1.

h) Wheel and axle. Principle of moments: develop from work principle. Equilibrium when moments balance.

i) General case of equilibrium. No translation when forces in opposite direction balance. No rotation when moments about any point balance.

6. **Energy of motion. Potential energy lost equals kinetic energy gained**

a) Piledriver, falling body, bullet; pendulum. Middle of swing, $s = 0$, but it has a velocity; also has its energy. Cannot measure its energy by Fs since $s = 0$. Hence we must substitute for s the velocity acquired in falling a distance s. By experiment show s proportional to V^2.

b) Relation of s to V in falling bodies. From $a = V/t$ and $s = V/2t$, eliminate t and find $s = V^2/2a$. Hence $Fs = FV^2/2a$.

*c) Note that weight is not active at the middle of swing. Yet bob of same material, but twice the size, has twice the energy. Notion of mass. How measure mass? From $Fs=FV^2/2a$; agree to measure mass by F/a. Call it m. Then $m=F/a$, or $F=ma$. In case of gravity: weight=mass$\times g$. Summary. Newton's second law.

d) Absolute units: of mass, gm.; of force, dyne; of work, erg.

*e) Weight is proportional to mass, since g is the same for all bodies. Density, as gm. per cm3.

f) Conceive pendulum string cut during the middle of the swing. Bob moves horizontally. How far? Notion of inertia. Energy of motion remains constant unless dissipated. Summary. Newton's first law.

g) Summary. General statements of the conservation of mechanical energy.

7. Power, as rate of doing work

a) Need of knowing power. Historical rating of engines from the treadmill. Horsepower defined in foot-pounds, gm.-cm., and watts.

8. Action and reaction: momentum remains constant

a) Common examples, as man on slippery floor, boy jumping from boat, child in swing, train and earth, etc. Force between the two the same: $F=mA=Ma$. Applied for the same time t, so that $mV=Mv$.

b) Impact.

9. Rotation

a) From general experience give idea of rotary inertia, as in fly-wheel, top, etc. Manifestations of inertia in centrifugal action, as in loop-the-loop, drying machines, cream separator, etc.

b) Quantitative relations, $f=mv^2/r$. Rotary energy$=Iw^2/2$.

10. Work done by fluids, measured by pressure times volume that flows

a) Water motors, windmills, turbines, steam engines to show work done by fluids.

b) Measurement of work done by fluid as pressure times volume that flows developed from the expression Fs.

c) Summary. Necessity of flowing from higher to lower pressure. How get the water or wind or steam at higher pressure? Extension of the ideas of conservation of work. Impossibility of perpetual motion. What about heat as energy?

HEAT

11. Conversion of work into heat: Joule's equivalent

a) Common cases of heat by friction, by compression of a gas, etc.

b) Measurement of heat. Temperature measured by sense of touch. Touch, not sensitive. Replace by expansion. Discussion of expansion of solids and liquids. Mercury thermometer, temperature scale.

*c) Expansion of gases, Charles' law, air thermometer, absolute scale.

*d) Measurement of quantity of heat, gm. cal. Specific heat.

e) Historical: Rumford, Davy, Joule, etc. and the determination of the ratio between the heat and the work units.

f) Summary and examples showing concretely the value of the joule equivalent: e.g., compute energy wasted when taking a warm bath.

12. Conversion of heat into work. Conservation of energy

a) General uses of heat engines: steam, gasoline, gas, etc. History of the steam engine and of its effects on civilization.

b) Trace heat through a steam engine, showing what must be known to understand its working. Source of heat. Coal as a source of energy. Mechanical equivalent of 1lb. of coal.

**c*) Evaporation. Heat absorbed. Water vapor in atmosphere, condensation, clouds, rain.

**d*) Saturated vapors. Pressure depends only on temperature. Definition of boiling-point. Relative humidity, dewpoint.

e) Failure of early engines. Work of Watt. Cooling by expansion when work is done. Condensation. Cold storage, liquid air.

**f*) Freezing and melting. Heat of fusion. Special case of ice.

g) Summary. When work is done, temperature falls. General notions of conservation of energy.

13. Transference of heat energy: flows from higher to lower temperature

a) Common experiences of heat transfer, as hot poker, hot water and hot air heaters. Distinguish conduction and convection, and discuss them.

b) Common experiences with radiation. Sun and earth, grate fire, etc. Concept of transfer of energy by waves, as on water, stretched rope, etc. Necessity for medium. This medium not air. Notions of ether.

c) Radiation and absorption. Good absorbers are good radiators. All bodies are radiating heat at all temperatures. Radiation more intense at higher temperatures, and changes its nature, as heat to light at 520° C.

This portion of the syllabus is enough to make clear the proposed form and spirit. Before printing the remainder, we wish to find out whether such a syllabus meets with the approval of the physics teachers generally. In order to have as open a discussion of the matter as is possible, this suggested syllabus is now submitted, not only to the members of the commission, but also to those others who have shown interest in this matter. It has been discussed and approved by the members of the commission who are resident in Chicago, namely, by Messrs. E. E. Burns, C. H. Smith, W. E. Tower, and C. M. Turton. You are invited, whether you are a member of the commission or not, to send answers to the following questions:

1. Does the definition of the unit as given above seem to you to be what is needed? If not, please suggest changes and state your reasons for them.

2. Is the form of the syllabus, consisting of general principles to be learned for use and subheads as suggestions to the teacher, satisfactory? If not, please suggest a better form, with your reasons for the change.

3. Do you wish to have either the choice or the arrangement of the subject-matter changed? If so, please suggest changes with reasons for them. In answering this, note No. 6 in the definition of the unit.

4. Is the plan of starring topics for illustration in the laboratory more satisfactory than the old plan of a list of approved experiments?

Even if you have no changes to suggest, it is hoped that you will send answers. Though they be brief, it all helps. Answers should be sent in before December 15, so that the entire syllabus may then be completed. As before, they should be sent to C. R. Mann, University of Chicago.